SCIENCE FOR CERAMIC PRODUCTION

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MOISTURE EXPANSION OF CERAMIC TILES IN DOUBLE FIRING

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The effect of chalk, slag generated at the Severstal' Works, and Kachkanarskii slime on moisture expansion of ceramic facing tiles is investigated. It is established that chalk is the most effective in decreasing moisture expansion, slag is the next, and the weakest effect is shown by Kachkanarskii slime.

It is known that one of the most significant service parameters of glazed ceramic tiles for interior wall decoration is their crackle resistance. It is established that this property is not guaranteed by heat resistance testing or by specifying water absorption of finished tiles at the level of 16 – 24%. The most important property determining crackle resistance is the moisture expansion of tiles.

Moisture acting on porous ceramics causes its moisture expansion, i.e., increases its size. Under long-term service in humid interiors, ceramic facing tiles expand, which may cause the formation of hairlike cracks on the glazed surface. The risk of this defect, known as "delayed crackle," can be diminished by lowering the moisture expansion of the ceramic.

According to numerous researchers [1], enhanced moisture expansion arises due to the presence of an alkaline vitreous phase in fired ceramics. Alkali metal oxides that make up part of a tile mixture under fast firing do not have time to form a sufficient quantity of crystalline phases which have low moisture expansion. This process can be intensified by introducing oxides of alkaline-earth metals into the mixture.

The moisture expansion of ceramic material can be determined by two methods: static and dynamic ones. The dynamic method is based on establishing the dependence of the sample size on the duration of its stay in atmospheric conditions [2], in water, or in an autoclave. The static method consists in very precise measurement of the sample length before and after steam treatment in an autoclave. Such measurements are usually performed using a micrometer.

Moisture expansion in an autoclave depends on two factors: pressure and exposure. The role of these two factors is significant. There are data on autoclave tests under pressure of 0.2 – 1.7 MPa with exposure at the maximum pressure for 1 – 5 h [3]. According to the European testing standards, autoclave treatment of finished tiles should be carried out twice at a pressure of 0.5 MPa with a 2 h exposure. Following the practice of Spanish tile manufacturers (the Keraben Company), we made the test conditions twice as strict. An exposure for 6 h was maintained under a pressure of 1 MPa plus 2 h for heating – cooling. The results of moisture expansion of respective samples in such conditions exceed nearly 2.5 times the results of testing according to the European standard.

The Lira Keramika company has tested different tile mixtures including different calcium- and magnesium-bearing components. We have tested compositions containing waste generated in the magnetic separation of the Kachkanarskoe deposit ore rock [4], granulated slag generated in cast iron production at the Cherepovets Metallurgical Works of the Severstal' Company, and Belgorod chalk. The content of calcium and magnesium oxides in tile mixture components (based on chemical analysis data) is shown in Table 1.

We investigated compositions (Table 2) containing the specified components in different ratios. To identify the moisture expansion of ceramics, tiles of size 55 × 110 mm were prepared. The linear sizes of six tiles of each composition were measured with an electron micrometer before and after an exposure in an autoclave (at least four measurements for each tile). The moisture expansion was calculated as the

TABLE 1

Component	Mass content, %	
	CaO	MgO
Kachkanarskoe deposit waste	18.60	9.89
Severstal' Works slag	37.10	9.53
Chalk	55.80	0.23

[1] Lira Keramika Company, Moscow, Russia.

TABLE 2

Material	Content, %, in formula												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Clay:													
Bulakovskoe	20	20	20	20	20	20	20	20	20	20	20	25	20
Ukrainian	20	20	20	20	20	20	20	20	20	20	20	15	15
Sand	15	15	15	15	15	15	15	15	15	10	15	20	20
Chamotte	15	15	15	15	15	15	15	10	5	–	12	10	10
Severstal' Works slag	–	–	–	–	5	8	10	3	–	10	6	10	10
Kachkanarskoe slime	25	20	15	10	5	5	–	15	20	20	10	8	6
Chalk	5	10	15	20	20	17	20	17	20	20	17	12	19

TABLE 3

Parameter	Formula													
	Lira Keramika	1	2	3	4	5	6	7	8	9	10	11	12	13
Mechanical strength, MPa	17.78	16.20	16.34	17.98	7.80	15.86	20.00	15.94	19.30	17.20	21.40	23.30	21.20	16.30
Moisture expansion,* %	0.084	0.080	0.069	0.058	0.050	0.049	0.042	0.045	0.055	0.057	0.040	0.051	0.054	0.029

* In an autoclave for 6 h under 1 MPa pressure.

increase (percent) in the sample length after autoclave treatment. The test results are represented in Tables 2 and 3. The molding pressure in all cases was 30 MPa, the firing temperature 1100°C, and the firing duration was 38 min.

For reference purpose we also prepared samples of tiles according to the factory formula (wt.%): 40 Bulakovskoe clay, 5 Miloslavskoe clay, 1 bentonite, 16 sand, 14 chamotte, 6 feldspar, and 18 chalk.

According to the obtained data, for mixtures using Balakovskoe (typical brick) and Ukrainian (refractory) clay, an increase in the content of the Kachkanarskii waste does not significantly decrease moisture expansion. Ceramic tiles currently produced have moisture expansion of 0.084% and after introducing as much as 25% Kachkanarskoe waste the moisture expansion decreases only to 0.080%. At the same time, an increased content of chalk in the mixture produces a significant decrease in moisture expansion: to 0.050%. A partial replacement of the Kachkanarskii waste by slag, the content of chalk being equal, further decreases moist expansion. Thus, estimating the effect of all three components on decreasing moisture expansion, the most active is chalk, the next is slag, and the least effective is the Kachkanarskii waste.

Some experimental mixtures were subjected to semi-industrial testing at the Lira Keramika factory. Positive results have been achieved: low moisture expansion — about 0.050%, absence of cold crackling after the second firing, normal heat resistance, and satisfactory strength of finished tiles.

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